Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	
	)	
Service Rules for Advanced Wireless Services in the 2000-2020 MHz and 2180-2200 MHz Bands	)	WT Docket No. 12-70
	)	
Fixed and Mobile Services in the Mobile Satellite Service Bands at 1525-1559 MHz and 1626.5-1660.5 MHz, 1610-1626.5 MHz and 2483.5-2500 MHz, and 2000-2020 MHz and 2180-2200 MHz	)	ET Docket No. 10-142
	)	
Service Rules for Advanced Wireless Services in the 1915-1920 MHz, 1995-2000 MHz, 2020-2025 MHz and 2175-2180 MHz Bands	)	WT Docket No. 04-356

Comments of Greenwood Telecommunications Consultants LLC

Greenwood Telecommunications Consultants LLC is a Denver, CO. based technology and management consulting firm that has clients including cellular operators, wireless equipment and device companies, location based services and GPS/GNSS receiver companies. The principles have held executive management roles and technical roles and hold in excess of 75 patents in wireless and GPS fields. They have extensive experience in communications systems and radio design and in regulatory affairs and standards development.

Richard Lee -President	Christopher N. Kurby- Partner
rlee@greenwoodtel.com	chriskurby@greenwoodtel.com

TABLE OF CONTENTS

GLOSSARY of ACROYMNS

AWGN	Additive white Gaussian noise
dB	decibel
dBi	dB isotropic
dBil	dB isotropic linear (polarization)
DL	down link channel
F	Noise Figure
GHZ	gigahertz
GMR-1 3G	Geostationary Mobile Radio- 3G
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
kHz	kilohertz
km	kilometer
LTE	Long Term Evolution signal
MHz	megahertz
m	meter
ms	milliseconds
ns	nanoseconds
N_0	noise power spectral density
Rx	receive or receiver
SNR	signal to noise ratio
SINR	signal to interference + noise ratio
Tx	transmit or transmitter
UE	user equipment
UL	Up link channel

1.0 Introduction

This comment in response to the NPRM to address a set of FCC queries sought. We chose the questions we believe are among those more critical to the FCC's deliberations in regard to how to allocate the new AWS-4 band, specifically: 1) Meet broadband wireless competitive entry goals, 2) Mitigate interference, and 3) Consider alternative uplink frequencies that lie outside the AWS-4 spectra. We also comment on the question raised by the FCC regarding GPS/GNSS receiver adjacent band interference and OOBE protection.

2.0 Band Sharing

This section is in response to the questions asked on band-sharing. To address this we evaluated several band sharing scenarios between different operators and different and the same systems to identify if technical issues arise regarding the FCC's commercial operator sharing scenarios.

2.1 Spectrum Services "Neighborhood"

Starting with the proposed band plan, we first examine potential interference across different sharing scenarios.

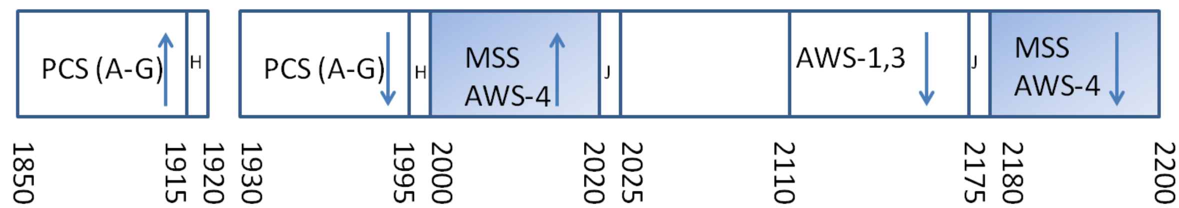

Figure 1. 1850 to 2200 MHz Spectrum Services Neighborhood

2.2 Band use Background

2.2.1 LTE Band Use Background

The LTE channel use is composed of 180 kHz wide resource blocks (RB) each themselves composed of 12 subcarriers that each contain15 kHz wide signals to form 180 kHz OFDM resource blocks. To simplify analysis we assume either up to operators would share the assigned 20 MHz spectrum as two independent 10 MHz channels. This case is shown below.

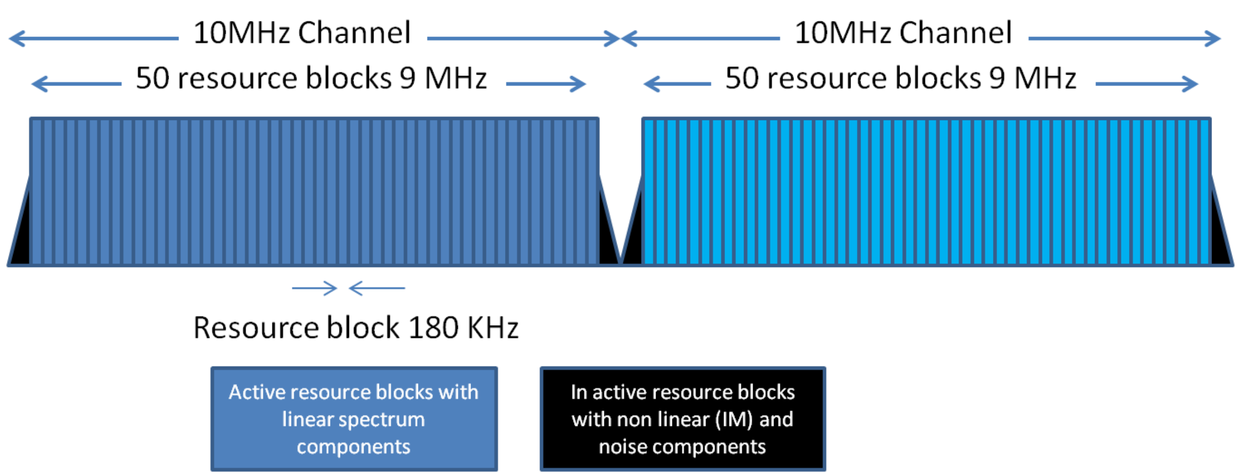

Figure 2. Adjacent 10MHz LTE channels

Figure 2 illustrates how each 10 MHz channel is occupied when two adjacent channels are fully occupied. It is possible at times that all the resource blocks are not occupied and this potentially provides some spectrum resource that can be occupied by other users from either the MSS domain or aggregated within other the LTE channel itself. However, this expansion is limited due to the noise and linear and nonlinear products generated in the transmitter. This is shown below in Figure 3. Following the same color key in Figure 2, the black regions are composed of noise and spurious modulation side bands or IM products, herein called intraband emissions. The undesired power in these gaps will affect the usefulness of communications using these compromised spectrum gaps in most applications.

The use of the 10 MHz channels is described in the next section.

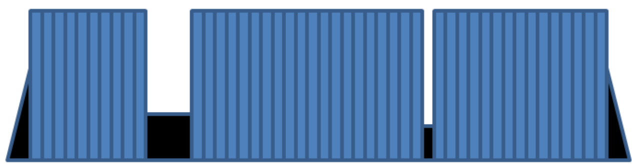

Figure 3. Example of an Underutilized 10MHz LTE Channel

In this case the unused resource blocks have a noise (including IM and modulation) floor which limits their use for either within the same operator or the adjacent operator. The amount of the noise in each resource block is specified in the user equipment by [1] in Table 6.5.2.3.1-1 and must be derived using a rather complicated calculation method.

In-band emissions are measured as the ratio of the UE output power in a non–allocated RB to the UE output power in an allocated RB. The analysis shows simplifies to -25 dB when the transmission BW is the same as the 3GPP defined Configuration BW of 9 MHz as would be the case for two independent 10 MHz operators. This is 5 dB worse than the adjacent channel leakage ratio of 30 dB and is expected given that the intermodulation power within the band will typically be higher than the intermodulation products falling outside the assigned LTE channel.

For a typical 23 dBm UE transmit power limit and available equipment specifications, we determined that the residual power within the unused resource block for the two extreme cases of 1 unused RB and another case of 49 unused (1 used) RB. We also assume that in the case of 49 unused RB's that the nearest other system use is 4.5 MHz away from the single used RB.

Table 1. Intraband Emissions for a 23 dBm UE

Offset from closest RB	RB's used	Spectrum dBr(RB)	Spectrum dBm/Hz (Gant=0dBi)	Spectrum dBm/Hz (Gant=-6dBi)
1 (180KHz)	49	-18.14	-64.68	-70.68
3(540 KHz)	49	-18.34	-64.88	-70.88
25(4.5MHz)	1	-42.00	-71.55	-77.55

These intraband emissions power levels are used later to evaluate same and different operator co-existence in band sharing.

2.2.2 MSS Band Use Scenarios

The use of the 10MHz band for MSS is unknown but we do know from [2] that the Terrestar plan is to use GMR-1 3G for MSS services. We can use [3] to make certain good assumptions for use in the MSS-LTE sharing analysis. The first observation is that the fundamental channel BW is 31.25 kHz. How these channels are deployed in each of the current Terrestar MSS spot-beams in terms of frequency reuse pattern is not important for this analysis.

We also assume that the MSS system is dominated by handsets of type 10 (or E) [3] which have the following characteristics.

Table 2. MSS GMR-1 3G Parameters

MSS Tx	**MSS type 10**	
Gant avg	-2.9	dB
Gant 90%	-0.3	dB
EIRP 90%	30.8	dB
EIRP avg	28.2	dBm
MSS Rx	**MSS type 10**	
Gant avg	-7.5	dB
Gant 90%	-2.8	dB
G/T 90%	-31.8	dB
Tsys	29	dBk
kTsys	-169.60	dBm/Hz

2.3 Band Use Options

The MSS/AWS-4 band can be assigned to two independent operators in several ways where each of the spectrum organizations has its own technical issues to be addressed.

2.3.1 Two Adjacent Terrestrial AWS-LTE Operators

The first case is that of two independent LTE operators where each operator occupies its own 10MHz bandwidth as shown in Figure 4. Now in 3GPP this scenario is accounted for in the specifications as this is common in spectrum allocations for greater than 10 MHz UL x 10MHz DL. In fact the 3GPP specifications allow for the operators to be the same or different as shown in the figure. The generation of the 3GPP specifications was performed by conducting extensive system simulations that account for out of band emissions (OOBE), receiver blocking specs and signal power levels. The protection metrics mentioned above were adjusted (within the working group) until an acceptable balance between throughput and blocking was found. Moreover the operator sites were not expected to be co-located (which will minimize interference) but the co-existence analysis allowed for the worst case positioning of the two operators exactly interleaved between each other. The analysis was also done to allow for other systems to co-exist other than only LTE with an adjacent LTE system   LTE it also included WCDMA with an adjacent LTE system and other combinations as well. Thus by definition this case is fully allowed and no more analysis is needed.

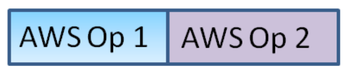

Figure 4. Two Adjacent AWS Operators

2.3.2 Two Concurrent AWS Operators

The option or scenario to be addressed is where the two operators operate independent LTE networks as seen in Figure 5.

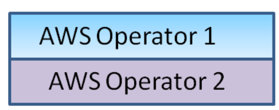

Figure 5. Two Concurrent AWS Operators

In general the analysis is taken from the perspective of the UE (or handset used interchangeably herein) rather than the satellite or the eNB (base station). This is because the UE's are all located on the ground and used in the same way no matter if the link is a handset to a satellite or to a. Also regarding OOBE with fixed equipment adding very high Q cavity filters to improve OOBE or Rx selectivity is fairly easy and of reasonable cost and is not further analyzed here. This simplifies the analysis and is highly useful in understanding if the spectrum use is possible or not.

In the case of two concurrent operators each operator use the same resource blocks instantaneously as seen in Figure 5 which attempts to depict the spectrum use. Thus they can overlap in time and frequency and yields a worst case signal to interference or effectively a SNR of 0 dB if all signals are perfectly aligned. In spread spectrum systems this is allowed since the processing gain can improve the signal to noise ratio of 0 dB by the ratio of the chip rate to the user bit rate providing offering tens of dB improvement. In LTE OFDM, this form of direct sequence spreading gain is not available.

Still this is not impossible as Shannon's law says that the received E_b/N_o only needs to be -1.59 dB for successful data transmission and when the bit rate equals the transmission symbol rate, as is the case for BPSK or QPSK the SNR = the E_b/N_o. Actually in this case the proper analysis is signal to noise + interference ratio or SINR as we assume the interference can be considered to be noise like and thus there is 1.59 dB of theoretical margin to a 0 dB SINR signal. However, even the best Turbo codes only come within 2 dB of the theoretical E_b/N_o limit and so the required E_b/N_o or SINR is at least +.41dB. This is higher than the available 0 dB SINR. By using forward error correction coding, already assumed, and lowering the user data rate (as opposed to increasing the symbol rate) the E_b/N_o can be improved by 10*log10 (1/R), where 1/R is the code rate. For example if the code rate R = 1/3 then the E_b/N_o is improved by 4.77 dB over the SINR. In this analysis, for BPSK the E_b/N_o is 4.77dB compared to the required +0.41dB for 4.3 dB of margin. However the throughput at this low an E_b/N_o according to Shannon will also be less than the modulation can support at higher E_b/N_o so this E_b/N_o level is really useless. Also imperfections in the receiver will also require at least 1 dB of margin in a good receiver and so the margin drops to 3.3 dB. This means that the signal power from the independent signals must be within 3.3 dB affecting fading performance and placing demanding requirements on power control . Additionally both must use the same coding and data rate which removes flexibility in provided service, taken together with the power control the system becomes deficient in terms of delivering a useful data rate.

The difficulty now reverts to the ability for the receiver to recover the BPSK symbols now at 0 dB C/I. This is very difficult and requires signal processing not normally available for LTE and even if available would still be limited in how much the C/I rate can get worse than 0 dB and still work. The obvious conclusion is this use case is untenable.

The only way this spectrum arrangement can work is if both operators manage the spectrum as one system. In this way each operator knows what resources blocks are assigned by the other and avoids using those. However this is extremely difficult and for absolute knowledge and maximum throughput this quickly degenerates to a single operator system. In this case there is no second operator and the premise collapses.

2.3.3 A Concurrent MSS and AWS Operator Case

We now turn to the case of two concurrent operators one AWS/LTE and one MSS/GMR-1 3G. This case is not much different from that of two concurrent AWS operators and is actually worse. This is worse because the two modulation system will not be same and so one of them will suffer from interference worse than the other for the same transmitter power level. Generally MSS requires more transmitter power than a terrestrial AWS system; this is partially achieved by transmitting a lower data rate which means the SNR for the MSS is higher in the same noise BW as an AWS system. In the case of GMR-1 3G the MSS channel BW is 31.25kHz while for one resource BW of AWS LTE this is 180kHz.

Thus the LTE system will be interfered to a higher degree than the MSS network since its BW will include all the energy of a single channel MSS system by as much as 6 times greater. Moreover the MSS GMR-1 3G power levels for a handset can be as high as 30.8 dBm which far exceeds the typical LTE power level of 23 dBm in the desired transmission BW as low as 180kHz.

Thus this case is also infeasible without extremely close coordination between the two independent operators.

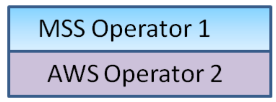

Figure 6. Concurrent Independent MSS and AWS LTE Operators

2.3.4 A Concurrent AWS/MSS Operator with an Adjacent AWS Operator

In this case we assign one 10 MHz segment to one operator who provides both MSS and AWS services in this block. A second adjacent 10 MHz block is assigned to another operator providing AWS/LTE service. We already know from section 2.3.1 that the adjacent LTE operators can coexist by definition of the 3GPP standards. Next we need to determine if the single AWS/MSS operator can use the 10 MHz spectrum for the two services. This can be done in two ways.

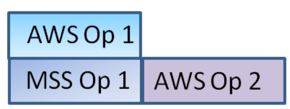

Figure 7. A Concurrent ASW/MSS Operator with an Adjacent AWS Operator

First the spectrum can be assigned by operator 1 in a static method where some frequencies are assigned to MSS service and some to LTE depending on the location. In urban areas they can assign the 10 MHz band to AWS only and the opposite in rural areas. In the simplest case the operator could use its 10 MHz band as a 5 MHz AWS band and as a 5 MHz MSS band system for both LTE and MSS. Ideally in the transition regions they could partition this as is needed. In the case of LTE it appears that some RB's could simply be avoided allowing them for use in MSS but the LTE and MSS network standards may not support this odd frequency use and hence the equipment providers will likely not support this. From a frequency sharing perspective this is completely feasible. (Note there are self-interference issues which are addressed below separately).

Alternately this can be done in a dynamic way where the transition region is very fluid or does not exist at all. It is unclear if any network standards or equipment exists to support this but it certainly is feasible although this may not evolve for some years to come.

Still if the same operator (Operator #1) channels are not used by the Operator #1 system this does not mean they are automatically useable by the Operator #1's system 2. This is because of the intraband emissions of the other channel. In the case of LTE referring to section 2.2.1 we know that the LTE unused RB's have intraband emissions power shown in Table 3. Similarly the MSS system also has residual power due to adjacent channel power. The table below compares the residual power for MSS and LTE.

Table 3. Intraband Emissions for MSS and LTE vs. Frequency Offset

Emissions	Offset (MHz)	LTE (dBm/Hz)	MSS-GMR (dBm/Hz)
in band 49RB's	0.18	-70.65	-60.57
in band 49RB's	0.5	-70.85	-60.57
in band 1RB	4.5	-77.54	

From this table in appears that LTE RB's can be interleaved in a consecutive set of 6 unused MSS channels which span 180kHz since its residual power of about -70 dBm/MHz is less than the MSS residual power but the opposite is not true. Thus even the same operator must make provisions outside of the GMR-1 3G standard [3] to allow for MSS channels to be interleaved within LTE spectrum. While theoretically feasible through extra emission control, this is likely impractical since it is extremely burdensome and demanding on equipment providers to supply such capabilities.

Thus the MSS/AWS-LTE operator is most likely to segment the available spectrum blocks as shown below.

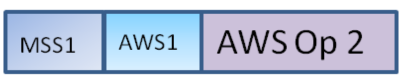

Figure 8.   A Concurrent ASW/MSS operator and an Adjacent AWS Operator V2

The issue at hand becomes the interference between one operators MSS system and their LTE system. Here the issues of inter system blocking and OOBE are at least contained in one entity. While the individual interference standards do not guarantee coexistence the operator is free to control other parameters as necessary to coexist making this very feasible.

3.0 Interband OOBE

We will only address the issues of the proper levels of OOBE for the frequencies between 1850 and 2025 MHz in the case of UE emissions.

3.1 Assumptions Used

In order to provide guidance on the proper limits we generate an interference analysis for UL's into DL's or mobile handsets transmissions into mobile receiver for the several proposed levels of interference from transmitters. OOBE for the different rule forms suggested by the FCC , 3GPP and ETSI are shown below.

Rule 1 FCC General OOBE	EIRP < 43 + 10 log (P) dBc/MHz
Rule 2 FCC Alternative OOBE	EIRP < 70 + 10 log (P) dBc/MHz
Rule 3 for PCS	EIRP < -30dBm/MHz
Rule 4 3GPP LTE Tx OOBE into LTE Rx	EIRP < -50dBm/MHz for a 0dBi antenna
Rule 5 GMR-1 3G for MSS	Power< 54 dBc/30kHz

We also have to set parameters on the UE's and the UE to UE interference scenarios of [4] and [5].

When developing new performance specifications where few parameters have been defined, it is prudent to use worst case values to remove any doubt in interference analysis and to set indisputable protection levels if feasible. But when working with previously defined parameters then one must approach the analysis from a more realistic perspective is was done here.

3GPP in [4] and [5] set UE to UE distances of 1 m for indoor and 5 meters applying 0 dBi antenna gains and 2 dB miscellaneous blockages. Regarding handset LTE antenna efficiency, typically an internal antenna has 25% efficiency which results in an average gain of -6dBi. This is in contrast to 3GPP's use of 0 dBi which is possible for some specific vectors from the UE toward another but is not an average gain which we choose to use here. The handset-to-handset separation is set to be 1 m same as in [5] for indoor cases.

We also choose to use the 3GPP value of 2 dB to account for body blockage. The 2 dB value is selected as we could assume at least some head or other blockage will occur between the two devices. The MSS antenna values are taken from [3].

Table 4. LTE and MSS antenna parameters

Ant to Ant								
	LTE	Units	comment			MSS	Units	comment
Gant Tx	-6	dB	experience 25%		Gant Tx avg	-2.9	dB	GMR-3G spec
Gant Rx	-6	dB	efficiency each ant		Gant Rx avg	-7.5	dB	GMR-3G spec
Body block	-2	dB	3GPP		Body block	-2	dB	3GPP
Net coupling	-14	dB			Net coupling	-12.4	dB	

We also use the blocking performance of the LTE spec for wideband and narrow band interferers as given in [1] and the out of band blocking for GMR-1 3G [3].

We also only consider LTE coexistence with MSS GMR-1 3G to limit the number of scenarios to the most likely ones in the future.

We also only consider OOBE and blocking performance using 5 MHz of guard band separation. This represents the minimum separation between a terrestrial PCS band DL and the proposed AWS-4 UL. (It is instructive to note that blocking performance for both LTE and MSS/GMR-1 3G do not improve from the 3GPP specification between 5 and 10MHz. However the OOBE is 12dB better (-25dBm/MHz) for LTE at 10 MHz frequency separation. Additionally there are provisions in the [5] to command the LTE handset to meet the more stringent level through network control although this is presently reserved only for a single band different than the ones considered here.

3.2 Analysis of OOBE in the PCS DL Band and the AWS-4 DL Band from 2175 – 2200 MHz

The analysis results are given per interference scenario and provide the blocking analysis next to the OOBE analysis with the different OOBE rules.

Table 5. MSS into PCS blocking and OOBE

Blocking			
MSS UL into PCS LTE DL-Blocking			
Rule	equation	3GPP	
Delta from band edge	(2000-1995)	5	MHz
P MSS avg	a	28.2	dBm
Gant MSS	b	-2.9	dB
PL(2GHz,1m)	c	38.47	dB
Gant LTE Rx	d	-6	dB
Body Blockage	e	-2	dB
P at LTE Rx	f=a+b-c+d+e	-21.17	dBm
Rx blocking(narrow band)	g	-55	dBm
Margin	h=g-f	-33.83	dB

OOBE						
MSS UL OOBE into PCS LTE DL						
Rule	equation	GMR	43log(P), -13dBm/MHz	FCC 70log(P), -40dBm/MHz	-30dBm/MHz	
Delta from band edge	(2000-1995)	5	5	5	5	MHz
P MSS 90%	a	30.8				dBm
Gant MSS	b	-2.9				dB
OOBE	c	-54				dBc in 30KHz
OOBE EIRP	d=a+b+c-44.8	-70.87	-73	-100	-90	dBm/Hz
PL(2GHz,1m)	e	38.47	38.47	38.47	38.47	dB
Gant LTE Rx	f	-6	-6	-6	-6	dB
Body Blockage	g	-2	-2	-2	-2	dB
OOBE at LTE Rx	h=d-e+f+g	-117.34	-119.47	-146.47	-136.47	dBm/Hz
KT of LTE Rx (F=9dB)	i	-165	-165	-165	-165	dBm/Hz
Margin	i-h	-47.66	-45.53	-18.53	-28.53	dB

Table 6. LTE into PCS blocking and OOBE

LTE UL into PCS LTE DL-Blocking			
Rule	equation	3GPP	
Delta from band edge	(2000-1995)	5	MHz
P UE	a	23	dBm
Gant UE (25% efficieny)	b	-6	dB
PL(2GHz,1m)	c	38.47	dB
Gant LTE Rx	d	-6	dB
Body Blockage	e	-2	dB
P at LTE Rx	f=a+b-c+d+e	-29.47	dBm
Rx blocking(wide band)	g	-56	dBm
Margin	h=g-f	-26.53	dB

LTE UL OOBE into PCS LTE DL						
Rule	equation	3GPP	43log(P), -13dBm/MHz	FCC 70log(P), -40dBm/MHz	-30dBm/MHz	
Delta from band edge	(2000-1995)	5	5	5	5	MHz
P UE	a	23				dBm
Gant UE (25% efficien	b	-6				dB
OOBE	c	-50				dBm/MHz
OOBE EIRP	d=a+b+c	-116.00	-73	-100	-90	dBm/Hz
PL(2GHz,1m)	e	38.47	38.47	38.47	38.47	dB
Gant LTE Rx	f	-6	-6	-6	-6	dB
Body Blockage	g	-2	-2	-2	-2	dB
OOBE at LTE Rx	h=d-e+f+g	-162.47	-119.47	-146.47	-136.47	dBm/Hz
KT of LTE Rx (F=9dB)	i	-165	-165	-165	-165	dBm/Hz
Margin	i-h	-2.53	-45.53	-18.53	-28.53	dB

Table 7. PCS LTE into MSS blocking and OOBE

PCS UL into MSS DL-Blocking			
Rule	equation	GMR-3G	
Delta from band edge	(2180-1915)	265	MHz
P UE	a	23	dBm
Gant UE (25% efficieny)	b	-6	dB
PL(2GHz,1m)	c	38.47	dB
Gant MSS Rx avg	d	-7.5	dB
Body Blockage	e	-2	dB
P at LTE Rx	f=a+b-c+d+e	-30.97	dBm
Rx blocking	g	-35	dBm
Margin	h=g-f	-4.03	dB

PCS UL OOBE into MSS DL						
Rule	equation	3GPP	43log(P), -13dBm/MHz	FCC 70log(P), -40dBm/MHz	-30dBm/MHz	
Delta from band edge	(2180-1915)	265	265	265	265	MHz
P UE	a	23				dBm
Gant UE (25% efficien	b	-6				dB
OOBE	c	-50				dBm/MHz
OOBE EIRP	d=a+b+c	-116.00	-73	-100	-90	dBm/Hz
PL(2GHz,1m)	e	38.47	38.47	38.47	38.47	dB
Gant MSS Rx	f	-7.5	-7.5	-7.5	-7.5	dB
Body Blockage	g	-2	-2	-2	-2	dB
OOBE at LTE Rx	h=d-e+f+g	-163.97	-120.97	-147.97	-137.97	dBm/Hz
KT of LTE Rx	i	-169.6	-169.6	-169.6	-169.6	dBm/Hz
Margin	i-h	-5.63	-48.63	-21.63	-31.63	dB

First we notice that OOBE rule 1 (43 + 10log(P)) provides poor inter system protection for these systems and we see that the OOBE limits the receiver more than the receiver blocking and as much as about 23 dB more indicating an imbalance in the specifications or rules for these scenarios.

Second the 3GPP protection levels of rule 4 provide good protection of both LTE receivers from Table 7 and for MSS from LTE in Table 8. This provides some support for the establishment of the OOBE level by 3GPP.

The GMR-1 3G OOBE Table 5 also appears to be deficient at the OOBE levels in the specification.

Now the OOBE for rule 2 (70 + 10log(P)) still provides seemingly inadequate protection but the OOBE levels provided are always better than the blocking level of the victim receiver except for PCS into MSS . This suggests that without a corresponding increase in the receiver blocking performance an increase in the OOBE will be of little benefit. Therefore the FCC should not require increased OOBE performance without a corresponding required blocking level. Any changes in both blocking performance and OOBE should be placed in the domain of the standards bodies and between operators themselves to agree on acceptable blocking and OOBE levels commensurate with their individual scenarios and needs.

Note that rule 2 should apply to all UL / UE devices in the band of 1850 to 2025 to provide mutual protection of OOBE to all systems. In the case of the PCS LTE emissions into the AWS 4 DL band or the AWS-1 band starting at 2110 this is fairly easy since the duplexers will have attenuation in these bands. In general, 3GPP specifications provide a necessary level of protection.

Recommendations:

1 Require 70 + 10*log10(P_t) OOBE rule for emissions into the 2110 to 2200 MHz band for mobile devices transmitting in the 1850-1915 MHz band.

2 Require 70 +10*log10(P_t) OOBE rule for emissions into the 1930-1995 MHz band for terrestrial cellular mobile devices operating in the 2000 -2025 MHz band.

Note MSS devices in the band of 2000-2005 MHz are addressed elsewhere.

4.0 GNSS Interference Protection

Regarding GPS and GNSS protection questions raised in the NPRM, GPS/GNSS receivers operates between 1559 and 1610 MHz which is several hundred megahertz of frequency separation from the proposed UE devices transmitting between 2000-2020 MHz.

4.1 OOBE

This analysis applies the same methodology for OOBE from either up or downlink cellular to into adjacent cellular bands. Here are the analytical assumptions.

GPS receiver front-end noise figure: 2dB

GPS antenna gain: -5dBi at the horizon is set at linear the same as determined by the GPS/LightSquared TWG [6] and close to the average antenna gain of representative cellular handsets' GPS antenna performance referenced in [7] at -4.4dB.

Separation distance: 1 meter (This is the same as cellular UE to UE separation) horizontal. Also included is a 5 meter physical device separation case.

We evaluate the three prevailing rules for OOBE into the GNSS band of 1559-1610 MHz band.

Rule 1: The EIRP < -70dBW/MHz same as ITU-RM.1343-1

Rule 2: The EIRP < -50dBm/MHz (-80dBW/MHz) which is the same as 3GPP for LTE OOBE falling into other LTE Rx bands

Rule 3: The EIRP is set to limit interference to a 1dB increase in GPS noise floor, or C/No for the 1m and 5m meter separation distances.

Table 8. GPS/GNSS Receiver Desensitization for Different OOBE Rules

OOBE into GPS Receiver						
Scenario	equation	**ITU-R M.1343-1**	**3GPP to protect DL's**	**Target 1m**	**Target 5m**	
OOBE EIRP at horizon	a	-70	-80	-105	-91	dBW/MHz
Gant GPS at Horizon linear	b	-5	-5	-5	-5	dB
Body Blockage	c	-2	-2	-2	-2	dB
Distance	d	1	1	1	5	m
PL(1.575 GHz)	e	36.40	36.40	36.40	50.38	dB
OOBE at GPS	f=(a+b+c-e+30-60)	-143.40	-153.40	-178.40	-178.38	dBm/Hz
KT(GPS,F=2dB)	g	-172	-172	-172	-172	dBm/Hz
OOBE/KTF(GPS)	=f-g	28.58	18.58	-6.42	-6.40	dB
GPS desense	10Log((g+f)/g)) linear)	28.6	18.7	0.9	0.9	dB

This analysis above indicates that a proper OOBE level on mobile terminals to protect GPS is -105dBW/MHz power spectral density. This is 35 dB greater than OOBE rules place on most UE devices, including the Big LEO MSS UE terminals operating between 1610-1626.5MHz band. There are several possible reasons why the current -70dBW/MHz level has not appeared as a problem for GPS from MSS terminals and hundreds of millions of cellular devices in general.

1) To date it is believed relatively few MSS terminals operate near GPS receivers. It is also likely that instances of MSS interference will increase at least as fast as the forecast units in the field, which is expected to be 7-15 times by 2018 [8].

2) MSS LEO networks historically were mostly used for low-use voice almost exclusively in remote, sparsely populated areas. MSS usage is currently shifting toward ubiquitous data services and latency-tolerant applications. These services have more competitive connection pricing that are reaching down to cellular pricing models (though MSS data throughputs are much less) making this threat more concerning in the near future

In the case of cellular handsets:

1) The cellular terminals exceed the -70dBW/MHz specification readily because they have duplex filters which further reduce OOBE levels within the GPS/GNSS band. Most cellular handsets have GPS embedded in them they already have to eliminate self-interference (in addition to blanking if used) to protect their own GPS receivers and derivatively protect surrounding GPS receivers as well.

2) Cellular antennas are narrow band thus add a degree of attenuation after the transmitter at GPS/GNSS frequencies.

While it seems extraordinary to require handsets to meet an extreme level of -105dBW/MHz we should recognize that the cellular antennas are narrow band as noted above. Cellular devices that operate with large offsets from GPS would have far less difficulty in meeting levels as low as -105dBW/MHz. Some devices (e.g., “Big LEO” MSS) will have more difficulty because enough filtering will be difficult to attain and the MSS device antennas have less selectivity relative to others well separated from the GPS band. But for higher operational frequencies of 1700 MHz or higher this should be commercially attainable.

4.2 GPS Blocking (Adjacent Band Interference)

In this section, we calculate the blocking levels required to Protect GPS/GNSS receivers from UE's in the 2 GHz frequency region. We use the same parameters as for OOBE with the following exception. All GPS antennas will have some inherent selectivity. Thus there will be some added attenuation at 2GHz to isolate the GPS receiver from UE transmissions. A commercial example is the Sarantel SL1200 [7] GPS antenna which has in excess of 30 dB coupling loss at 2000 MHz and above. Since we cannot account for the various antenna selectivity's we determine blocking protection requirements based on a flat 0dBi gain GPS antenna. When an implementer selects his antenna design he can adjust the blocking signal power at the receiver to account for the actual antenna selectively.

Table 9. GPS blocking vs Distance and Antenna Gain

GPS Receiver Blocking					
Scenario	equation	0dB gain GPS ant	-30dB gain GPS ant	5m distance	
P_Tx UE	a	23	23	23	dBm
Gant UE (25% efficieny)	b	-6	-6	-6	dB
Distance	c	1	1	5	m
PL(2 GHz)	d	38.47	38.47	52.45	dB
Gant GPS at Horizon linear	e	0	-30	0	dB
Body Blockage	f	-2	-2	-2	dB
P at GPS Rx	=a+b-d+e+f	-23.47	-53.47	-37.45	dBm

It is significant to note that in [8] some precision GPS receivers were tested for blocking susceptibility to closer in frequency MSS system to GPS namely those within 1610 to 1660 MHz. These signals also degraded GPS performance and high light the fact that blocking is not restricted to cellular only terrestrial signals and that current threats also exist and will get worse as quantities of MSS users increases.

Certain categories of GPS/GNSS receivers are susceptible to adjacent band signals such as transmissions from L Band LEO or GEO MSS uplinks. Thus, an overall improvement in spectrum utilization as well as avoiding increasingly probable interference to susceptible GPS receivers cannot be realized until both forms of cross-band interference are addressed together and with equal effect.

Recommendations:

We recommend receiver protection requirements be adopted for GPS/GNSS receivers to mitigate adjacent band interference susceptibility as soon as possible. Acting quickly gives the GPS industry and their customers’ time and needed clarity to address design improvements in adjacent band susceptibility margins for both new, and to an extent fielded precision GPS receivers. Wideband precision receivers are currently undergoing upgrade and replacement over the coming years to take advantage of Modernized GPS signals currently being added to the GPS constellation.

Given available evidence there is no reason to impose a different OOBE standard on AWS-4 handsets than other handsets. There are many million devices today operating at transmitter frequencies closer to the GPS/GNSS band than is proposed for AWS-4. We therefore recommend the FCC not change OOBE specifications exclusively for AWS-4 devices. We recommend a gradually timed rule change to increase OOBE levels within the GNSS for all UE band to ultimately reach -105dBW/MHz based on a 1m horizontal separation distance. This rule should follow a timeline preceding if necessary equivalent rules defining receiver protection standards in GPS receivers. This parallel path (i.e., tighten OOBE and adjacent band protection) provides the highest spectrum utilization with the least cost for all stakeholders.

5.0 Guard Band between 1995 and 2000 MHz

The FCC poses a question about guard band sufficiency. First we address the 5 MHz guard or transition band between the 1995 PCS and 2000 MHz MSS bands. This offset is insufficient for handsets to transition from $43+10*\log(P_t)$ to $70 + 10\log(P_t)$ as post amplifier duplex filters cannot provide much attenuation across such a limited amount of frequency separation. The figure below from an UE component supplier, Avago Technologies, was taken from the published FCC TWG report [6]. The Avago BAW filter shown here would indicate that 10 MHz transition is sufficient for the 1500 MHz band to provide at least 40 dB of attenuation.

At 1541 MHz representing a 5MHz transition or guard band the filter seems to also provide 40dB attenuation but this does not account for the temperature and make tolerance frequency drift of the filter. Attenuation values are better judged by 3 to 5 MHz above the 40 dB value at about 1542 MHz where the 3 to 5 MHz offset becomes 1545 to 1547 MHz which provides only a few dB of attenuation. Obtaining 40dB of attenuation at 2000 MHz with a 10 MHz transition band will more difficult since the offset relative to the stop band frequency is less but is very likely attainable including make and temperature tolerance.

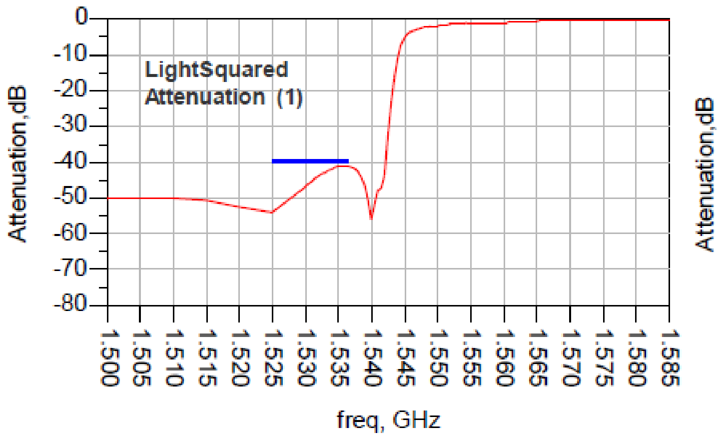

Figure 9. Representative UE Duplex Filter Performance versus Frequency Separation

6.0 Band Use Proposal

The previous sections described OOBE levels desired to protect PCS DL from AWS-4 ULs and described the difficulty in reaching these levels with only 5 MHz of guard or transition band. The FCC recognized this and offered up several band plan alternatives to address this. We describe a different band use alternative below which we believe optimizes spectral utilization.

We propose that the MSS UL band be extended to 25 MHz to include the lower J block. We also propose that the lower 5 MHz of 2000 to 2005 MHz be allocated to MSS UL on a secondary basis while the remaining 20MHz can be flexible use for LTE UL's and MSS. The secondary use of the lower 5 MHz for MSS will remove the need to improve OOBE for these devices since the user density is low and the likelihood of proximate users between MSS and PCS is low. Then the more stringent -70dBW/MHz can be imposed on devices above 2005 MHz proving the necessary 10 MHz for filter design. This allows Terrestar to maintain their full satellite 10MHz capability and achieve 20 MHz of LTE as well. It also sets a path for Terrerstar to migrate their satellites in the future to use 2005 to 2015 for MSS as satellites are replaced and the 2000-2005 band becomes occupied by primary users.

The upper J block then can be made available for auctions which would be valuable to either AWS-1 or AWS-4holders to expand their existing DL capacity.

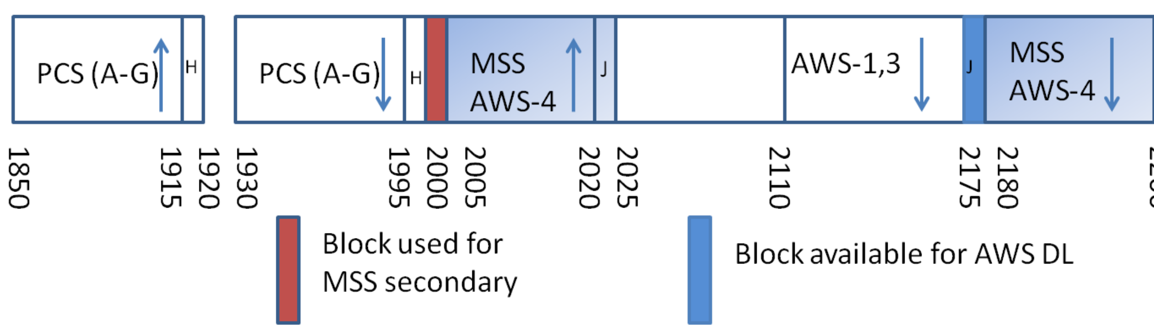

Figure 10. Proposed Band Plan

Alternately, the FCC could require Terrestar to surrender their MSS only band of 2000 to 2005 MHz sometime in the future when new satellites are launched capable of operating in the 2005 to 2015 MHz. The useable BW would then be reduced to 20 MHz flexible use UL.

The FCC would then have 10MHz available at 1995 to 2005 MHz for limited but still useful Small Cell options such as low power indoor TDD operations.

Recommendations:

Assign the 2005-2025 MHz UL band paired with the 2080 -2200MHz DL band AWS-4 to a single operator who can best manage traffic and interference parameters thus achieve highest utilization of the AWS-4 spectrum.

Reallocate a segment of the original AWS-4 UL proposal between 2000-2005 MHz to accommodate legacy MSS UL to become a secondary service for legacy MSS operations.

Allocate two 5 MHz bands to form a 10 MHz, 1995 to 2005 MHz band for broadband services for Small Cell low power indoor (most likely LTE TDD).

Allocate the 2175 to 2180 MHz J block for AWS-4 DL services.

7.0 Summary of Recommendations

Table 10. Summary

Query Issue	Recommendations
OOBE for mobile devices transmitting in the 1850 to 1915MHz band	Require 70 + 10*log10(P_t) OOBE rule for emissions into the 2110 to 2200 band for mobile devices transmitting in the 1850-1915 MHz band.
OOBE for mobile devices in the 2000-2025MHz band	Require 70 +10*log10(P_t) OOBE rule for emissions into the 1930-1995 band for terrestrial cellular mobile devices operating in the 2000 -2025 MHz band.
Protection of GPS from out of band carriers	We recommend receiver protection requirements be adopted for GPS/GNSS receivers to mitigate adjacent band interference susceptibility as soon as possible. Acting quickly gives the GPS industry and customers' time and needed clarity to improve adjacent band susceptibility margins in both new, and to an extent fielded precision GPS receivers. Wideband precision receivers are currently undergoing upgrade and replacement over the coming years to take advantage of Modernized GPS signals currently being added to the GPS constellation.
Protection of GPS from OOBE for mobile devices	Given available evidence there is no reason to impose a different OOBE standard on AWS-4 handsets than other handsets. There are many million devices today operating at transmitter frequencies closer to the GPS/GNSS band than is proposed for AWS-4. We therefore recommend the FCC not change OOBE specifications exclusively for AWS-4 devices. We recommend a gradually timed rule change to increase OOBE levels within the GNSS for all UE band to ultimately reach -105dBW/MHz based on a 1m horizontal separation distance. This rule should follow a timeline preceding if necessary equivalent rules defining receiver protection standards in GPS receivers. This parallel path (i.e., tighten OOBE and adjacent band protection) provides the highest spectrum utilization with the least cost for all stakeholders.
Band plan	Assign the 2005-2025 MHz UL band paired with the 2080 -2200MHz DL band AWS-4 to a single operator who can best manage traffic and interference parameters thus achieve highest utilization of the AWS-4 spectrum. Reallocate a segment of the original AWS-4 UL proposal between 2000-2005 MHz to accommodate legacy MSS UL to become a secondary service for legacy MSS operations. Allocate two 5 MHz bands to form a 10 MHz; 1995 to 2005 MHz band for broadband services for Small Cell low power indoor (most likely LTE TDD). Allocate the 2175 to 2180 MHz J block for AWS-4 DL services.

8.0 References

[1] 3GPP TS 36.101 V10.2.1 (2011-04), "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception"

[2] Terrestar Product Specification, http://www.terrestar.com/

[3] ETSI TS 101 376-5-5 V3.2.1 (2011-02)," GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 5: Radio interface physical layer specifications; Sub-part 5: Radio Transmission and Reception; GMR-1 3G 45.005"

[4] 3GPP TR 136 942 V10.2.0 (2011-05) "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios"

[5] 3GPP TR 25.942 version 10.0.0 Release 10 ETSI "Universal Mobile Telecommunications System (UMTS); Radio Frequency (RF) system scenarios"

[6] TWG Final Report, Appendix G.2. ftp://twg:freeforall@ftp.novatel.ca

[7] http://www.sarantel.com/products/sl1200

[8] C. Kurby, R. Lee, L. Cygan, E. Derbez, *Maintaining Precision Receiver Performance while Rejecting Adjacent Band Interference,* Proceedings of the 2012 ION Meeting, Newport Beach CA, January 2012.
http://www.ion.org/search/view_abstract.cfm?jp=p&idno=9987